THE ORBITING GEOPHYSICAL OBSERVATORIES

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The National Aeronautics and Space Administration has been engaged in a diversified research program to acquire geophysical data relative to phenomena in terrestrial and extraterrestrial space. Experimental data in these programs have been obtained from spacecraft launched by a series of increasingly powerful launch vehicles, with the nature and scope of the experiments limited largely by the payload capacity of the vehicles. These limitations of weight caused early spacecraft to be tightly integrated systems of experiments and basic spacecraft subsystems, with resultant difficulties in disassembly and repair or replacement of assemblies if discrepancies occurred during checkout or testing. However, developments in launch vehicles in the past few years led to the conception of spacecraft as standardized containers or carriers for experiments. Because of the increasing payload weight capability of the launch vehicles, it was possible to think of the spacecraft subsystems and the experiments as separate portions of the same system, with the capability existing to integrate any of the subsystems singly into the entire system. From this background, the "observatory" concept was developed.

The concept of an observatory allowed consideration of a standard spacecraft, standard in the sense of incorporating a high degree of flexibility for accommodating many types of scientific and technological experiments and of operation in a wide range of orbits for periods up to a year. In this manner, it would not be necessary to design and develop a new spacecraft for each mission; instead a spacecraft of the same design with only minor modifications could be used on successive missions to carry different combinations of experiments. In addition, the observatory could be considered in terms of the following five individual subsystems:

1. The basic structure of the spacecraft within which the assemblies of other subsystems and experiments would be mounted.

2. An attitude control subsystem for orienting the spacecraft properly to fulfill the directional requirements of various experiments.

3. A thermal control subsystem to maintain the temperatures of the assemblies and experiments within a desired operating range.

4. A power supply to supply electrical power to the experiments and other subsystems.

5. A communications and data handling subsystem to provide a degree of control of the spacecraft from the ground, to prepare and store experimental and spacecraft operational data, and to transmit these data to the ground.

The advantages that appear inherent in the concept of a standardized observatory include the following:

1. Capability of accommodating a large number of experiments per mission and of performing frequent missions. The frequent missions and large number of experiments that may be directly or indirectly related will allow study

and correlation of many phenomena at the same time and same point in space. For example, it will be possible to study simultaneously the relationship between solar events, the solar plasma, the earth's radiation belt, and the earth's atmospheric structure.

2. Provision of an attitude control subsystem to control the orientations of the experiments with respect to several different references.

3. Convenience to the experimenter in designing his instrumentation by providing a well-defined interface between the spacecraft subsystems and the experiments, thereby allowing each experimenter to integrate his instruments with a minimum of effort.

4. Improved reliability through repeated use and constant step-wise improvement of a basic spacecraft design in follow-on missions.

5. Provision of conservatively designed power, data handling, and thermal control subsystems for experiments, thereby permiting extreme flexibility in their design.

6. Advantage of being able to handle a limited number of relatively "high risk" experiments late in the program. These experiments would represent a small percentage of the total experiments.

7. Improved operational efficiency through the continued evolution and use of a ground station network, operating procedures, and data processing equipment and techniques.

8. Reduced cost of follow-on missions, on a experiment-pound basis, since development of a new spacecraft for each mission will be avoided.

9. Simplified data acquisition and data reduction, since tracking and data reduction equipment will be matched to a fewer number of different designs of spacecraft.

A number of observatories are being developed for the NASA scientific research program. The spacecraft include the Orbiting Solar Observatory (OSO), the Orbiting Geophysical Observatory (OGO), the Orbiting Astronomical Observatory (OAO), the Ranger and the Mariner. The first three observatories are being developed as a part of the NASA Goddard Space Flight Center earth satellite program. The Ranger and Mariner are being developed as part of the Jet Propulsion Laboratory lunar and planetary program.

PROGRAM OBJECTIVES

The primary objective of the Orbiting Geophysical Observatories (OGO) program, which is a part of the national space sciences long range program, is to conduct large numbers of significant, diversified experiments for making scientific and technological measurements about the earth. A secondary objective of the program is to design, develop, and have available for launching at regular intervals a standard observatory-type oriented spacecraft consisting of a basic system design that can be used repeatedly to carry large numbers of easily integrated experiments in a wide variety of orbits. As a design objective for the standard spacecraft, it is desired that the spacecraft be capable of operation for a period up to a year in a wide variety of orbits from near earth circular to highly elliptical cislunar.

During orbital operation, it is desired that portions of the spacecraft be oriented toward the earth, the sun, and in the orbital plane.

The current OGO program consists of two missions. The first observatory, the Eccentric Orbiting Geophysical Observatory (EGO), will be launched by an Atlas Agena B in mid-1963 from the Atlantic Missile Range into a highly eccentric orbit of approximately 31 degrees inclination. Its orbit will have a nominal perigee and apogee of 280 and 110,000 km respectively. This orbit will allow the observatory to traverse the radiation belts twice each orbital period and to make geophysical measurements from near the earth to interplanetary space. The Orbital period of EGO will be about 42.8 hours.

The Polar Orbiting Geophysical Observatory (POGO), will be the second mission in the program. POGO will be launched into a polar orbit in early 1964. Launching will occur with a Thor Agena B from the Pacific Missile Range. The POGO orbit, with perigee and apogee of 250 and 920 km respectively, will allow the measurement of the characteristics of the ionosphere over ranges in latitude and altitude and the making of observations of many phenomena directly over the polar regions.

Over-all weight of the observatories will be approximately 1000 pounds, of which 150 pounds will be experiments and their associated equipment.

Future geophysical observatories will be assigned to specific orbits as required by the experiments, within the capacity of launch vehicles. In addition, advanced versions of the spacecraft design may have increased weight carrying capabilities or may be launched into higher orbits as launch vehicles of increased capability are developed. The present OGO spacecraft is designed with a growth potential such that it can be expanded to an observatory of 1500 pounds. Most of the increase in weight will be available for experiments. Included in the growth potential may be the capability of carrying and separating in orbit a 300 pound pickaback satellite to perform experiments requiring an especially "pure" environment or experiments which need large separations between two of their parts.

SPACECRAFT

OGO, being developed for NASA by Space Technology Laboratories, Inc, of Redondo Beach, California, is shown in the deployed configuration in Figure 1. The observatory, which consists of the spacecraft and experiments, is a rectangular parallelepiped with appendages mounted so that the entire system has the five degrees of freedom necessary to satisfy the requirements of experiments oriented in solar and anti-solar, geocentric and anti-geocentric, and orbital directions. The main body of the spacecraft is approximately 33 by 32.5 by 67 inches. Extending from the ends of the main body are two long booms approximately 25 and 21 feet in length. Experiments which might be affected by disturbances generated in the main body of the spacecraft are mounted in containers on the ends of these booms. These experiments include magnetic field experiments, whose accuracies would be affected by the small amount of ferromagnetic material which must be used in the spacecraft systems and by the magnetic fields produced by incompletely cancelled electric currents. Three shorter booms, 4 feet in length with experiment containers at the ends, extend from the end of the main body containing the spacecraft portion of the adapter between the launch vehicle and the spacecraft. An additional 4-foot boom with experiment container extends from the other end of the spacecraft. Experiments designed to measure the properties of the atmosphere, which might be influenced by small amounts of gas evolved from the subsystems, or carried from one position in space to another by semi-closed trapping volumes, are carried on the short booms. Experiments to measure the properties of the ionosphere are also mounted on short booms so the effects of the plasma sheath and the electrostatic potential can be minimized. Likewise, experiments whose results would be influenced by the presence of a nearby large mass are supported away from the main body. Solar arrays which have one degree of freedom relative to the main body are mounted on a shaft which extends through the sides of the spacecraft containing thermal control louvers. Containers for mounting solar and antisolar experiments are located on the ends of the arrays. The distance between the ends of the long appendages is approximately 49 feet and between the ends of the solar array approximately 20 feet. All appendages are designed to be folded into a launch configuration that will fit within a 56-inch diameter circle. After injection into orbit, the appendages are automatically sequenced to deploy and lock into position. Experiments that require orientation in the orbital plane are mounted in the orbital plane experimental packages (OPEPs) which rotate about an axis perpendicular to the long axis of the spacecraft. Antennas for reception and transmission are mounted on the short booms in a position to allow an unobstructed view for the geocentric oriented experiments.

STRUCTURE

The basic structure of the main body of the spacecraft is shown in Figure 2. Embodying a "refrigerator door" concept, the body of the spacecraft is constructed of aluminum fabricated in a modified sandwich design. The geocentric and anti-geocentric faces of the spacecraft can be opened on the ground for easy access to the subsystems that are mounted internally and on the lower one-third of the doors. The upper two-thirds of the doors, which can be opened separately from the lower portions, are reserved for experiments. In addition, in the upper one-fourth of the main body, a completely open volume exists between the doors. This volume can be used for additional small experiments, or for a very large single experiment. The gas bottle for the pneumatic system, shown at the bottom of the observatory, is fabricated of titanium. Torsional rigidity of the structure is obtained by the ends of the spacecraft, the solar array shaft, and removable internal braces which can be bolted into position. Four longerons in the corner of the spacecraft together with the vertical panels absorb acceleration loads during launch and transmit them to the modified square mounting attachment at the base of the spacecraft.

ATTITUDE CONTROL

The attitude control subsystem must be capable of reducing the transients imposed during injection and separation, efficiently acquiring the sun, earth, and orbital plane during the initial sequence, reacquiring for a limited number of times if any of the sensors loses its reference, and controlling the observatory during normal orbital operations. Desired pointing accuracies during orbital operation are as follows:

Geocentric	± 2 degrees
Solar	± 5 degrees, except it may be ± 20 degrees within 30 degrees of the noon condition
Orbital	± 5 degrees (POGO)
	± 5 degrees (EGO), when the orbital angular rates of EGO equal or exceed the rates of POGO.

The attitude control system, consisting of sensors, servos, and torquing devices is shown in Figure 3.

The actuating assemblies of the attitude control system consist of inertia wheels, solar array and OPEP drives, and pneumatic jets using argon as a propellant. Argon is used because of the requirements of some experiments, especially in POGO, of being capable of measuring constituents of the atmosphere having molecular weights less than that of nitrogen.

Horizon scanners, which track the infrared gradient of the horizon and are mounted on a pylon on the main body of the spacecraft (Figure 2), provide the error signals for maintaining the orientation of one surface of the spacecraft in a geocentric direction. Inertia wheels and jets provide the torques about the roll and pitch axes.

Rotation about the yaw axis to maintain the shaft of the solar array normal to the sun-observatory vector and the louvered sides of the spacecraft parallel to the same vector and the louvered sides of the spacecraft parallel to the same vector is controlled by a large yaw inertia sheel and gas jets. The necessary error signals are provided by sun sensors mounted near the ends of the shaft. These error signals are transmitted to the solar array drive which rotates the array about its shaft to keep it normal to the sun to provide the maximum solar energy at the solar cells.

The orbital plane experimental packages (OPEPs) are controlled in yaw to point in the orbital plane. Since the yaw axis of the main body is controlled to point in a geocentric direction, this implies that the OPEPs will point perpendicular to the observatory-earth line, and therefore along the velocity vector in circular orbits and at apogee and perigee in elliptical orbits. The OPEPs are contrdled by an OPEP drive which is identical with the solar array drive. Error signals for the OPEP drive are derived from an integrating gyro (with a redundant backup) operating in a gyrocompassing mode. Since this control is dependent upon gyrocompassing, operation will be optimum only when the body angle rates are high -- near perigee for EGO and throughout the entire POGO orbit.

The inertia wheels, which are identical for pitch and roll, are used mainly to remove the cyclic momentum disturbances. However, the wheels also absorb non-cyclic disturbances, so that it is necessary to desaturate (dump) the wheels by use of the pneumatic system when their momentum storing capacity is reached. Non-cyclic disturbances such as the acquisition sequence, aerodynamic torques, solar radiation pressure, and separation transients are absorbed by the pneumatic system.

The solar array and OPEP drives are modern applications of the wabble gear, a device that has been known for many years. Since the angular rates associated with control of the array or the OPEPs are quite low, a large speed reduction between the drive motor and the drive is necessary. The wabble gear fulfills this requirement by the wabbling of the non-rotating driving gear which at the same time causes the driven gear to rotate. Speed reduction is obtained by having a one-tooth difference in the number of teeth on the driving and driven gears. The driving gear is designed as a part of a container wall of a sealed package in which a pair of metallic, convoluted bellows flex to match the non-rotating, wabbling movement. In this manner, the drive motor and intermediate gears and bearings are contained within a sealed container which prevents escape of lubricants from within and internal contamination by external particles.

To avoid slip rings between the rotating solar arrays and the OPEPs and the main body of the spacecraft, flexible wiring is used. However, this design imposes the requirement of yawing the spacecraft through 180 degrees twice per orbit to reverse the direction of rotation of the arrays and the OPEPs. Control for this maneuver is provided by the yaw inertia wheel which is approximately twice as large as the pitch and roll wheels. Since this yaw or "noon turn" maneuver occurs twice per orbit in opposite directions, the yaw wheel will not become saturated during the turns.

The block diagram of the attitude control system is outlined in Figure 3. Notations near the switches in the subsystem indicate the operation of this subsystem during the modes of boost, null and search (acquisition), and normal operation. During boost, the subsystem is caged in the Mode I position. In the null and search mode (II) following separation from the Agena B and deployment of all appendages, body rates are nulled by the reaction wheels and jets actuated by rate signals derived from the sun sensors on the solar arrays and from a pitch rate gyro.

Following nulling of the body rates, the acquisition sequence automatically, with ground command backup, is initiated with the solar arrays being caged normal to the longitudinal axis of the observatory. In this position, error signals from the sun sensors cause the longitudinal axis of the observatory to be aligned with the sun-satellite line; after this maneuver, the observatory is rotated slowly about the longitudinal axis until the horizon scanners eventually intercept the earth. After earth acquisition, the solar array is uncaged and the spacecraft is both pitched and rolled to remain earth orieated while the array remains normal to the sun. Orientation of the OPEPs with their gyrocompassing mode of operation is the last operation in the sequence. Once acquisition has been completed, the subsystem switches automatically into normal operation (Mode III). Loss of reference for any of the sensors providing error signals for the controls causes the subsystem to switch into the proper phase of acquisition (II).

THERMAL CONTROL

Thermal control to maintain temperatures of all assemblies within the main body of the spacecraft in the range 5 to 35°C will be accomplished by a combination of active and passive techniques involving temperature-controlled louvers and radiating panels on the two sides of the spacecraft through which the shaft of the solar array protrudes, and by use of an aluminized mylar radiation shield on the remaining surfaces of the spacecraft. Since the solar array will always be directed toward the sun, the louvered sides of the spacecraft should never see the sun and as such can control the radiant transfer of heat from the observatory. Bi-metallic actuators rotate the louvers to control the exposure of the radiation panels to space. The radiation barrier on the other surfaces of the spacecraft minimizes the transfer of thermal energy through these surfaces. With this combination of louvers, radiating surfaces, and barriers, a proper balance of energy input and output can be maintained to meet the temperature requirements. Subsystem components that dissipate large amounts of heat will be mounted on the relatively thick radiation plates under the louvers, thereby allowing good conduction to the areas exposed by the louvers.

Thermal control of the appendage containers will be obtained by use of a combination of radiation barriers and electrical heating. Radiation areas on the experiments are located and sized such that a proper heat balance can be maintained during periods of maximum energy input. Electrical heating will be used in the appendage containers during long eclipses or when the experiments are turned off. With this system, the temperatures of assemblies within the containers on the appendages should normally be between 0 and 40 degrees C.

Sensors that protrude through the radiation barriers on both the main body and the appendage containers and that must be protected from outgassing from internal components will be provided with appropriate seals. In addition, due to the large temperature difference seen by the solar array during normal operation and during eclipses, the experiment containers on the ends of the solar arrays must be well isolated thermally from the array.

POWER SUPPLY

The power supply subsystem, which supplies electrical power to all electronic assemblies and experiments, consists of a solar energy converter, nickel-cadmium batteries, and a charge control assembly. The solar energy converter consists of approximately 32,250 junction silicon cells (each 1 by 2 cm, with an effective area of 1.8 square cm) mounted on the arrays which are maintained normal to the sun. Maximum initial power is to be approximately 650 watts. Allowances for losses due to transmission, orientation, variation of the solar constant, accuracy of measurement, and cell matching result in an initial effective available power of approximately 490 watts at 29.5 volts. Degradation during a period of 1 year due to damage from radiation and micrometeroids is expected to reduce power output at the end of this time to approximately 300 watts for EGO. The reduction in available power for POGO is estimated to be much less, due to less severe radiation damage.

Twelve ampere hour batteries (approximately 75 pounds in two redundant packs) provide electrical power to the observatory during eclipse and assist in gross regulation of the power buss voltage. Nominal output voltage of the system is 28 volts, but may vary between 23.5 and 33.5 volts. No central regulator or converter is used; instead, regulation or conversion for subsystems or experiments are individual requirements.

Average total power required from the power supply subsystem is approximately 225 watts, dependent upon the eclipse time. Of this average power, peak and average powers of 80 and 50 watts respectively are available for experiments, and 22 watts for thermal control. The battery pack, with consideration of the factors of depth of discharge, numbers of discharge cycles, and reliable battery lifetime is sized for an eclipse of two hours for EGO. This requirement will impose some restraints of launch window on EGO, but these restraints will be relatively minor. Time in eclipse for POGO is approximately 35 minutes maximum, with a greatly reduced depth of discharge of batteries relative to EGO. However, the greater number of eclipses with POGO compensates to make the overall estimated performance equivalent for the batteries on either EGO or POGO.

Two redundant charge regulators introduce impedances between the solar arrays and the battery packs, thereby limiting battery buss voltage to a maximum of 33.5 volts. In addition, an undervoltage cutoff eliminates non-essential loads when the battery voltage falls below 23.5 volts.

COMMUNICATIONS AND DATA HANDLING

The communications and data handling subsystem of the spacecraft is provided to process, store, and telemeter experimental and spacecraft operational data; to receive, decode, and execute ground commands; to radiate an RF signal that will enable accurate orbital determination; and to generate both coded and uncoded timing signals for use by both the experiments and the spacecraft subsystems. The major elements of this subsystem are shown in the block diagram in Figure 4. The wideband data system is a high-capacity digital data system designed to condition, store, and transmit most of the experimental and spacecraft data to ground receiving stations.

Each of the two identical data-handling units includes a set of time multiplexers, or commutators, and an analog-to-digital converter. A large number of high- and low-speed input channels are provided in each data-handling unit.

Either analog or digital data can be accepted, depending on the basic nature of the data source. The output of one of the two data-handling units is recorded by one of two redundant magnetic-tape data storage units. The recorders each contain sufficient tape to store data at a rate of about one measurement per second from each of 128 inputs for 12 hours. They will be read out periodically by the ground stations at high speed. For the POGO orbits, the recording rate will be increased by a factor of four, so each recorder will have a 3-hour capacity.

The second data-handling unit will be used at a higher rate to telemeter data to the ground stations in real time. It is capable of making approximately 8 to 64 measurements per second from each of 128 inputs whenever commanded to do so from the ground. One of two redundant 400 megacycle transmitters using PCM/PM modulation will telemeter the data from the real-time data-handling unit or from the data storage unit as directed by ground command.

On EGO, the transmitter feeding the directional antenna will be used. In the event that this transmitter fails or the attitude control subsystem no longer points the directional antenna at the earth, the other transmitter and its omnidirectional antenna will be used. However, on POGO with its near earth orbit, the directional antenna will be replaced with a second omnidirectional antenna.

The second major portion of the communications and data handling subsystem is the special purpose transmitter. It is provided to telemeter data from experiments which are incompatible with the time sharing feature of the wideband system, or whose signals need to be telemetered in completely unprocessed form.

The command subsystem of the observatory contains the assemblies necessary for operational control of power to experiments and spacecraft subsystems, change of modes of operation of the communications and data handling subsystem, operational control, calibration, or change of scale factor in experiments, backup of initial sequencing of the spacecraft, and some switching of redundant equipment in case of failure. Two parallel command receivers indicated in the block diagram in Figure 4 receive ground commands on a frequency of approximately 120 megacycles. PCM/FM/AM modulation is employed. Two redundant digital decoders which operate normally with either decoder operative are provided to decode and execute digital commands. Digital commands numbering 256 comprise a large percentage of the total command capability. Of this number, 150 commands, including those commands required to control experiment power, are assigned to experiments. A few of the more important commands which can allow limited operation of the spacecraft in event of failure of the digital command system can be sent as tone commands and are decoded by a simple, high reliable tone decoder. In addition this tone command system, which uses sequential tone transmission, permits reception of real time wideband data at any Minitrack station without requiring these stations to have access to the digital command system.

Tracking of the observatory will be accomplished by a network of tracking stations located throughout the world. Three 136 mc beacon transmitters on the spacecraft will provide the tracking signals. Two of these are redundant low power (100 milliwatt) beacons, one of which will be on continuously. The third beacon is a high power beacon (10 watts) which is turned on intermittently by command for periods of 45 seconds to allow tracking with improved accuracy near EGO perigee. The high power beacon will not be included on POGO. The overall goal of the tracking program is to be able to determine for the experimenter the position of the observatory at any time within a sphere of uncertainty having a radius of 1 km or less at perigee and 100 km or less at apogee of EGO.

TRACKING AND DATA ACQUISITION

Data acquisition for both the EGO and POGO will be accomplished by both special primary and secondary stations and the Minitrack network. Selected stations will have the capability to receive and record, at the maximum data rates, all data from the wideband and special purpose telemetry. For the wideband telemetry, the signals will be demodulated from the RF carrier and recorded on analog magnetic tape. For the special purpose telemetry, a separate tape recorder will be provided.

Central control of the observatories will be from Goddard. Primary tracking and acquisition sites are Rosman, North Carolina, and Fairbanks, Alaska. Secondary sites are located in northwestern Australia, Johannesburg, South Africa, and Quito, Ecuador. All of the primary sites will have complete digital and tone command capabilities. All of the secondary sites and Minitrack stations will have tone command capabilities. In addition, secondary sites that "see" injection of EGO or POGO will have sufficient digital command capabilities to command the "backup" observatory deployment and acquisition phase. Injection of EGO will occur near the northwestern tip of Australia; for POGO, injection will occur near Madagascar. Injection will occur during the second burn of the Agena B, which coasts in a transfer eclipse following first Agena burn. Shroud separation will have occurred following burnout of the first stage Atlas or Thor for EGO or POGO, respectively.

Data links connecting Goddard with Rosman and Alaska will be used to give some degree of real time control of the satellites. Goddard central will have complete facilities to decommutate, extract, display, analyze, and print all data from the wideband and special purpose telemetry. It will not be necessary that all of these functions be performed in real time. However, real time performance to determine certain parameters, especially for experiments, may be required at specific times. Since the Rosman station, which has an 85-foot parabolic antenna, can see EGO approximately 50 percent of the time and because the OGO's are basically self-controlling spacecraft, the "taped data plus Rosman real time" approach will allow a large degree of control of EGO. For POGO, the real time limitations are more severe. Even with data links from both Rosman and Alaska to Goddard, real time control of POGO may be limited to approximately 10 percent of the time. Teletype systems to all of the other stations will allow preplanned commands from Goddard to be ready for transmission to the observatories when they come within range.

The operational flow of data from the observatories to Goddard is shown in Figure 5. All data from the secondary and Minitrack sites will be recorded on tapes and forwarded to Goddard for processing. Data received at the primary sites will be recorded and also forwarded to Goddard. However, both Goddard and the primary sites will have PCM data handling equipment. At Goddard, this equipment will be used to condition the wideband PCM signals, received via the link from Rosman and Alaska for computer entry and display. Likewise, a special purpose processer will condition the special purpose telemetry signals for entry and display. The computer will be used to perform automatic status checks on the spacecraft and for processing, or "refining," selected experiment outputs in real time. Control and display consoles at Goddard will be used for timing, routing, and display of the data, and for remote control of the ground recorders and PCM data handling equipment. Data such as time, station status, status of the observatory communications and data handling equipment, and the status of a "pass" will be displayed continuously. "Hard copy" display of the status of the spacecraft (housekeeping data) and a "quick look" at selected experiment outputs will be provided by a printer. The tape recorders will be used to record the regenerated, "clean" data from the output of the signal conditioner, and the raw unprocessed signal from the special purpose telemetry. Time code will also be recorded simultaneously with these signals.

Goddard will also possess a command console which will allow central control to "talk" to the observatory in real time via the links to Rosman and Alaska. This capability will permit automatic real time response to events occurring in space. The primary stations will also have PCM data handling equipment, with limited general purpose displays. This equipment will provide station operators at these stations with sufficient quick look capability for command verification, and will permit "cleaner" signals to be transmitted via the data link to Goddard. The result should be greater system flexibility and reliability.

Tracking data obtained from the network of Minitrack and primary and secondary stations will be forwarded to Goddard for computation of the orbital elements. Orbital predictions will be computed from these elements, and will be transmitted to the tracking sites to provide antenna pointing information for the stations to allow initial antenna acquisition at the beginning of each pass.

Following transmission to Goddard of tapes on which the telemetry signals are recorded at the remote sites, the tapes will be catalogued and processed. The general procedure will be to produce noise-free master computer tapes containing all raw data and orbital data. Individual computer magnetic tapes will be produced for each experimenter with the tapes containing his experimental data, spacecraft performance parameters, spacecraft orientation, orbital elements, and universal time. These tapes will be forwarded to each experimenter for further processing and analysis. The primary means for disseminating new information to the scientific and technological space committees will be through publication in the open literature.

EXPERIMENTS

Experiments for the OGO's are selected by the Office of Space Sciences, NASA Headquarters, Washington 25, D.C. Experiments are selected at appropriate times from those proposed by research groups in universities, industry, other government agencies, and NASA. Many of the experiments are the result of initial technical development that NASA has supported under its advanced development program. Selection of experiments has been completed for EGO and a list of these experiments, the experimenters, and their institutions is included below:

List of Experiments and Experimenters

Experiment Title	Principle Experimenter	Phenomenon Measured
Solar Cosmic Rays	XXX K. A. Anderson, Univ. of Calif.	Solar proton and x-ray flux, energy and variations.
Plasma, Electro-static Analyzer	XXX M. Bader, Ames Research Center	Solar plasma flux, energy and direction.
Plasma, Faraday Cup	XXX H. J. Bridge, Mass. Inst. of Tech.	Solar plasma flux, energy and direction.
Positron Search and Gamma Ray Spectrum	XXX T. L. Cline and XXX E. W. Hones, Goddard Space Flight Center and Inst. for Defense Anal.	Search for positrons and solar gamma ray flux and spectrum.
Trapped Radiation, Scint. Counter	XXX L. R. Davis, Goddard Space Flight Center	Geomagnetically trapped electron, proton flux, energy and direction.
Cosmic Ray Nuclear Abundance	XXX F. B. McDonald Goddard Space Flt. Center	Primary and solar cosmic ray flux, charge and energy.
Cosmic Ray Spectra and Fluxes	XXX J. A. Simpson, Univ. of Chicago	Primary and solar cosmic ray flux, charge and energy.
Trapped Radiation, Omnidir. Counters	XXX J. A. Van Allen, State Univ. of Iowa	Geomagnetically trapped electron and proton flux and energy.
Trapped Radiation, Electron Spectrometer and Ion Chamber	XXX J. R. Winckler and XXX R. L. Arnoldy Univ. of Minn.	Geomagnetically trapped electron energy and flux and total ioniza-tion.
Rubidium-Vapor and Flux Gate	XXX J. P. Heppner, Goddard Space Flt.Center	Magnetic field strength and di-rection.
Triaxial Search Coil Magnetometer	XXX E. J. Smith Jet Propulsion Lab.	Magnetic field low frequency variations.
Spherical Ion and Electron Trap	XXXX R. Sagalyn, A. F. Cambridge Research Lab.	Thermal charged particle density, energy, and composition.
Planar Ion and Electron Trap	XXX E. C. Whipple, Goddard Space Flt. Center	Thermal charged particle density, energy, and composition.
Radio Propagation	XXX R. S. Lawrence, Nat. Bureau of Standards	Electron density.
Atmospheric Mass Spectrum	XXX H. A. Taylor, Goddard Space Flt. Center	Atmospheric composition.
Interplanetary Dust Particles	XXX W. M. Alexander, Goddard Space Flt. Center	Micron dust particle, velocity and mass.
VLF Noise and Propagation	XXX R. A. Helliwell, Stanford Univ.	VLF terrestrial noise, solar par-ticle emissions, and cosmic noise frequency distribution and strength.
Radio Astronomy	XXXX F. T. Haddock, Univ. of Mich.	Solar radio-noise burst frequency spectrum.
Geocoronal Lyman-Alpha Scattering	XXX P. Mange, Naval Research Lab.	Lyman-Alpha intensity.
Gegenscheim Photometry	XXX C. L. Wolff and XXX K. L. Hallam, Goddard Space Flight Center	Gegenscheim intensity and location.

As indicated in the table, many of the experiments to be carried on EGO are directed toward investigations of fields and energetic particles. Selection of experiments for POGO has not been completed at this time.

Following selection of experiments, support of the experiments is assumed by Goddard. The experimenters and the OGO project staff work directly together to ensure that the experimental objectives are met. Approximately nine months before the scheduled launch date, prototype experiments will be brought to Goddard to be checked for compatability with spacecraft simulators that simulate the electrical interfaces that the experiment will see in the actual observatory. In addition, the prototype experiments will be subjected to environmental tests of vibration, shock, thermal vacuum, temperature, leak (for sealed units), acceleration, and magnetic fields to prove that the experiments are capable of withstanding the rigors of launch and the space environment and to determine their magnetic properties. Similar tests at lower test levels will be conducted on the flight units of the experiments.

Following testing at Goddard, experiments will be shipped to Space Technology Laboratories, where the experiments will be given additional bench and interface checks before integration into the observatory. The entire observatory will then be exposed to a series of environmental tests to determine that the entire system will operate together without interference and that it can withstand the launch and space environments. Environmental tests will be conducted with both a prototype and the flight model observatories. After completion of the environmental tests at the observatory level, the observatory will be shipped to the appropriate launch site, where it will undergo detailed hangar checkout before being placed on the launch vehicle. Successful completion of "on-pad" tests of the launch vehicle and the observatory together are required before launch will be initiated.

In summary, the Orbiting Geophysical Observatories are standardized but flexible spacecraft composed of easily removable subsystems and well defined interfaces for experiments such that the OGO's should be capable of use for a wide variety of missions in a number of different orbits. Standardization and flexibility in removing, replacing, or modifying experiments have been keynotes in the design of a system whose design should serve as a carrier for experiments for several years. A systems approach to the observatory, the launch vehicle, and the tracking and data acquisition should result in fulfillment of both the primary and secondary objectives of the program.

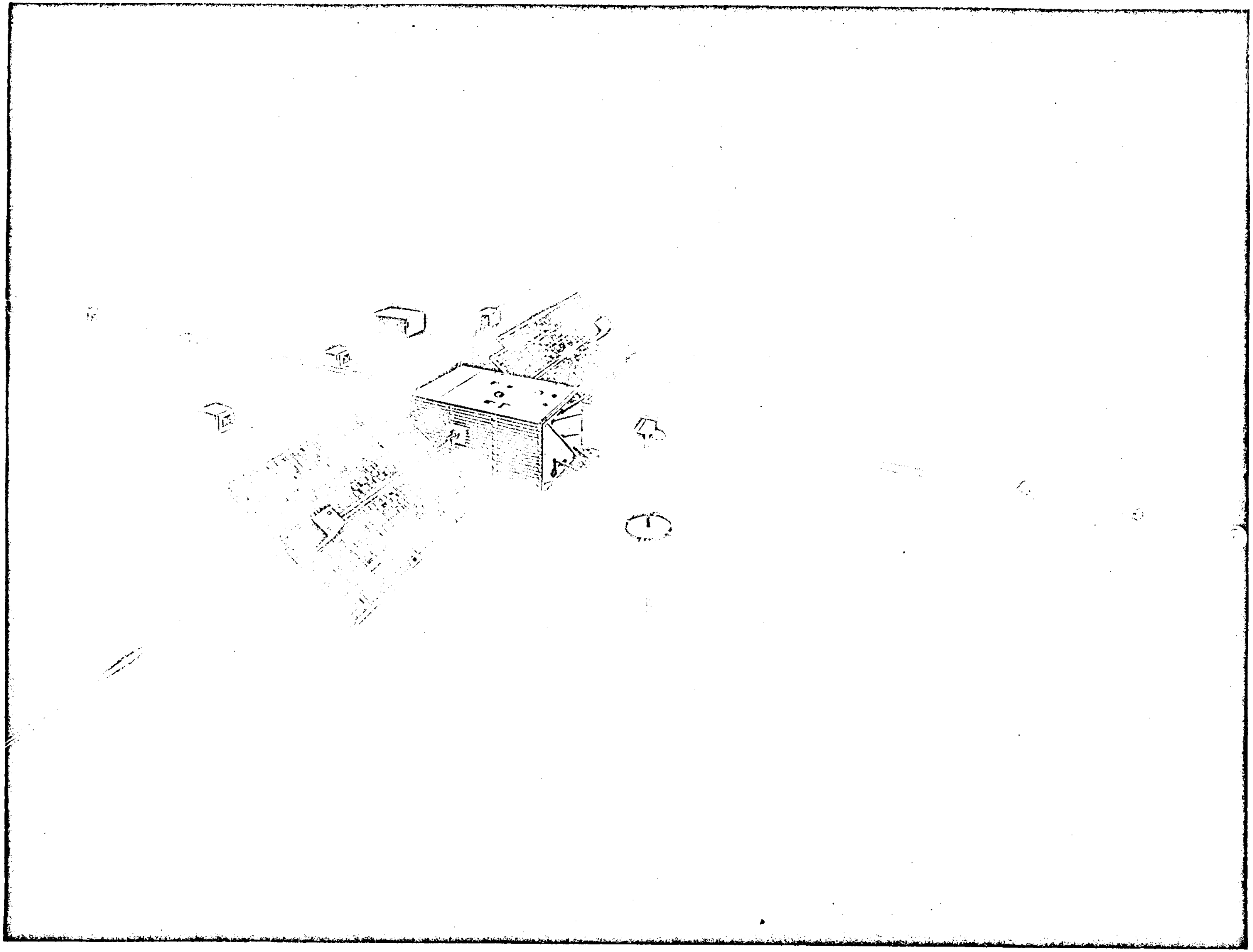

Figure 1. The Orbiting Geophysical Observatory

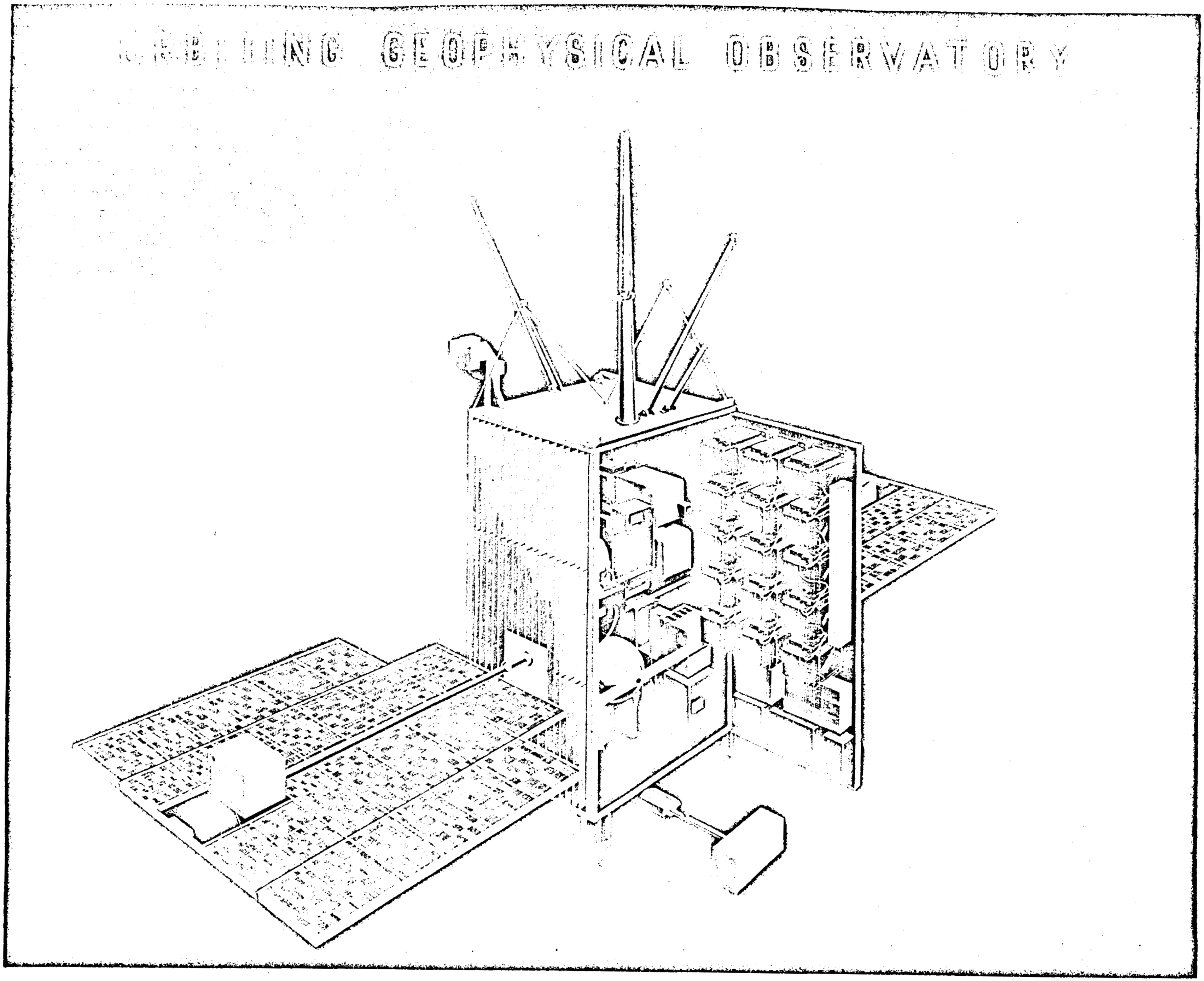

Figure 2. The Observatory with one of its doors open

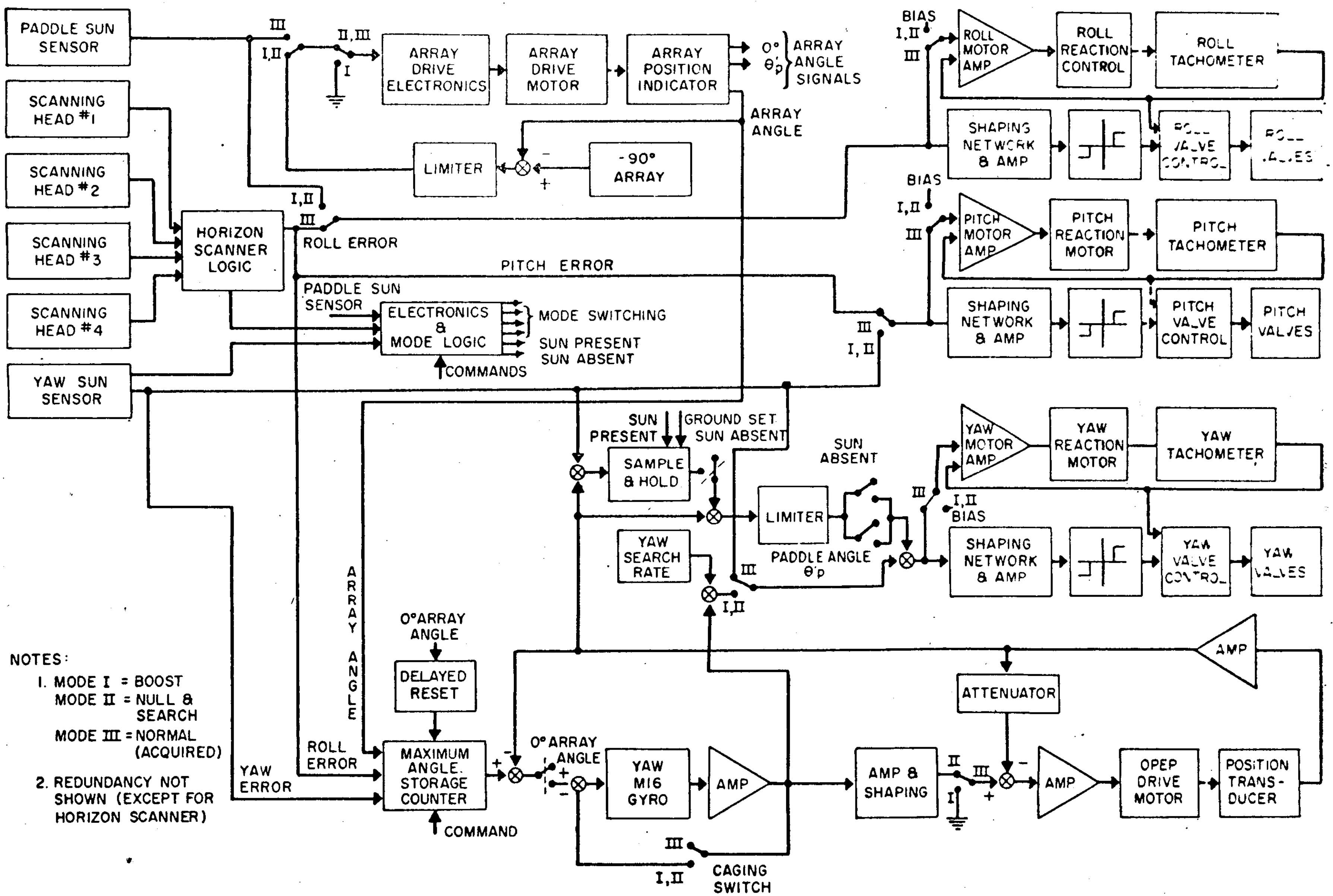

Figure 3– OGO Attitude Control Subsystem, Block Diagram

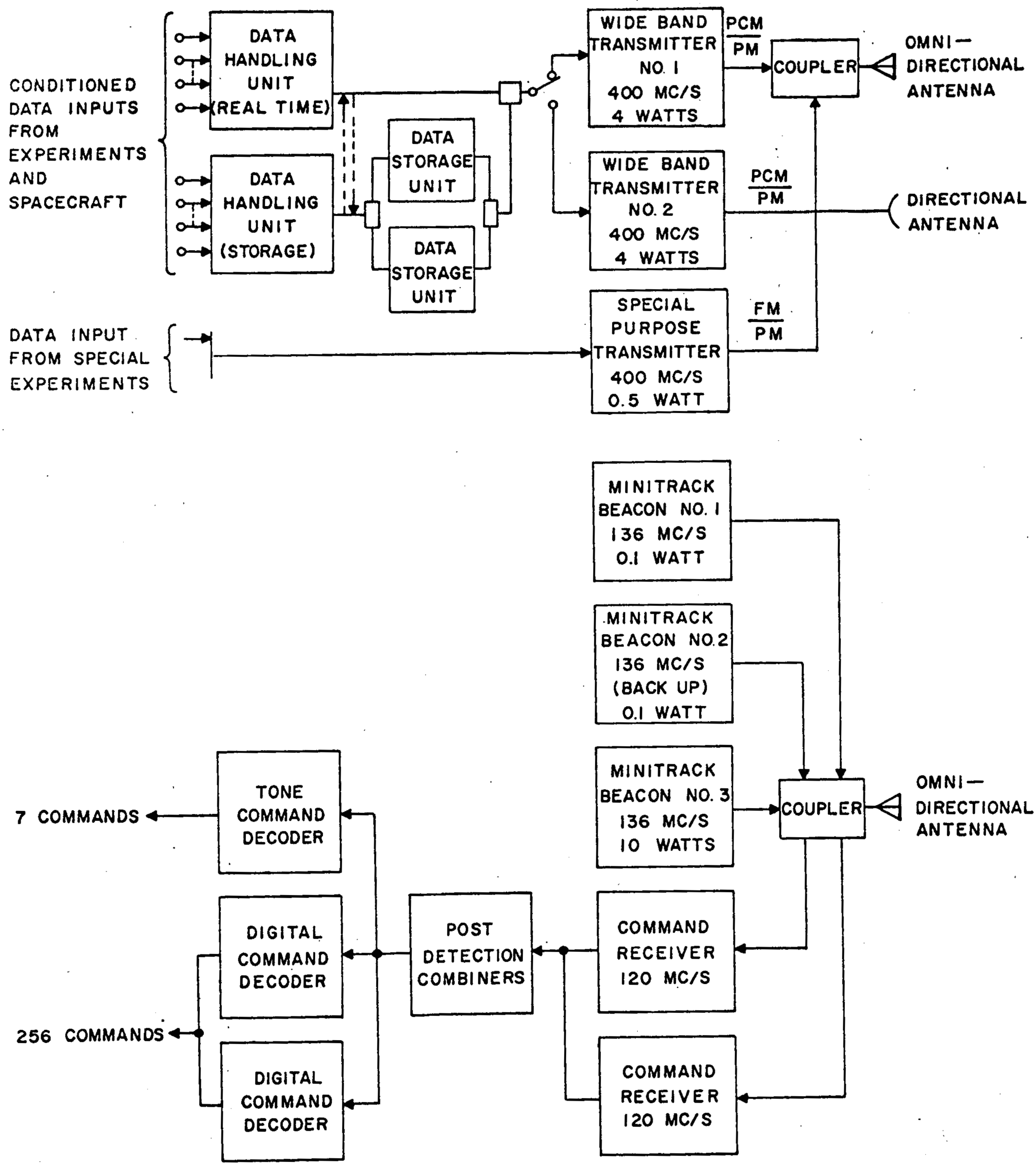

Figure 4. Block Diagram of the Data Handling and Communications Subsystem

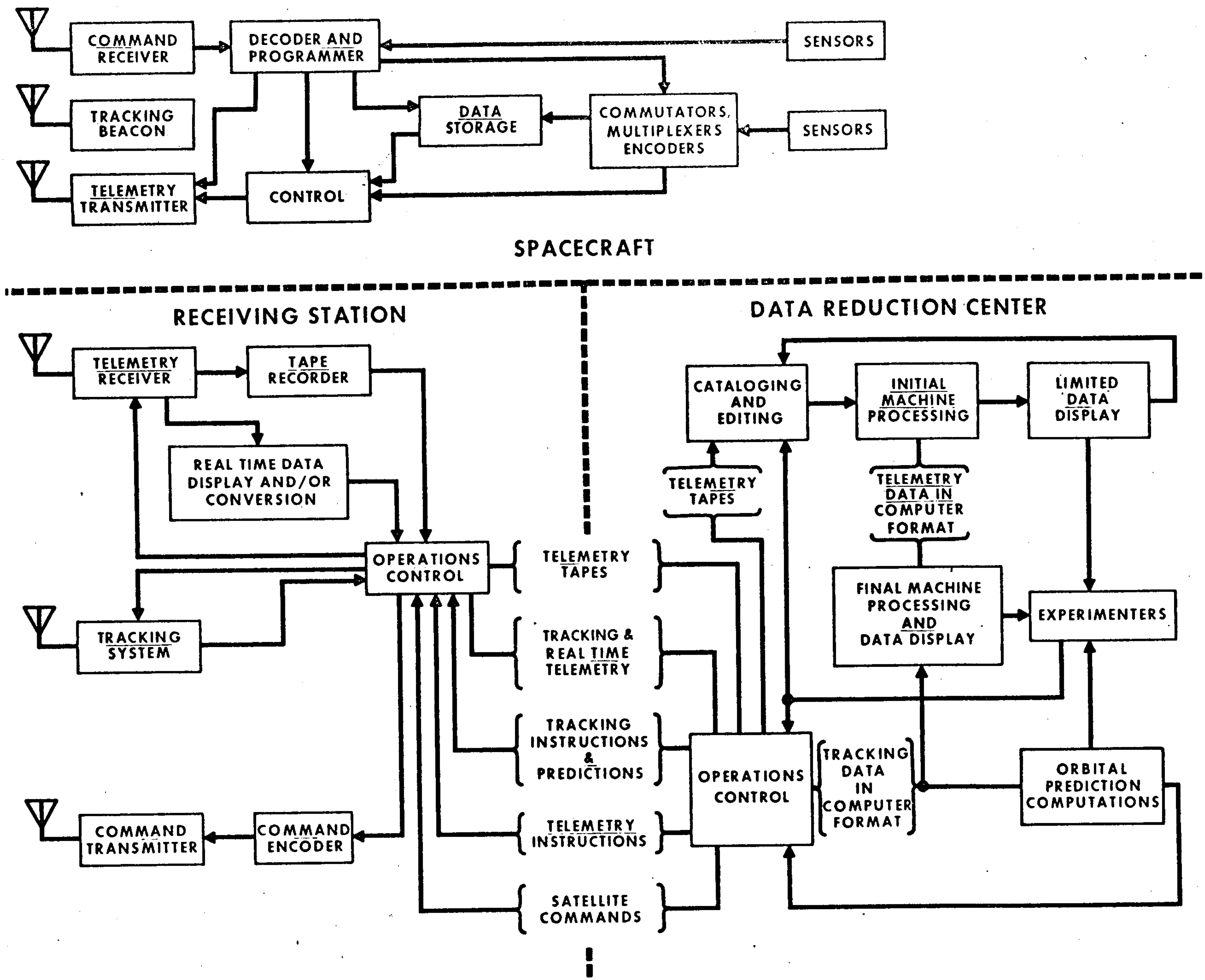

Figure 5. Flow Diagram Showing the Operation of the Observatory in Orbit

Figure Captions

Figure 1. The Orbiting Geophysical Observatory. The distance from tip to tip of the long booms is about 16.5 meters (54 ft.). The distance between ends of the solar panels is about 6 meters (19.5 ft.). The experiments for the first flight are shown in the appendages.

Figure 2. The Observatory with one of its doors open. Experiment assemblies are mounted on the upper two-thirds of this door and the corresponding door on the opposite side. Subassemblies for the support systems are mounted inside the main body. Many of the appendages are not shown. The length of the main body is 1.7 m (67 in.).

Figure 3. Block diagram of the attitude control system.

Figure 4. Block diagram of the data and communications system.

Figure 5. Flow diagram for operation of the Geophysical Observatory in orbit.

George H. Ludwig was born in Sharon, Iowa, on November 13, 1927. He received the B.A. degree with a major in Physics in 1956, the M.S. degree with a Physics major in 1959, and the PhD in Electrical Engineering in 1960, all from the State University of Iowa.

Prior to entering the University in February, 1953, he served in the U. S. Air Force as an airborne radar maintenance officer and pilot. As an undergraduate student he assisted in the designing and building of balloon and rocket borne instrumentation for cosmic ray research at high altitudes. He accompanied the State University of Iowa expedition to the Davis Strait in the summer of 1955 to use balloon launched rockets to investigate the cosmic ray intensity at high latitudes.

Since the beginning of 1956, Dr. Ludwig has worked on the design of satellite borne instruments for the investigation of cosmic rays and the Van Allen trapped radiation. As a graduate research assistant to Dr. J. A. Van Allen, he developed most of the corpuscular radiation instrumentation for Explorers I, II, III, IV, V, VII, and project S-46. Explorers I, III, IV and VII were successfully launched, and led to the discovery of the high intensity trapped radiation.

Since graduation in 1960, Dr. Ludwig has headed the Fields and Particles Branch Instrumentation Section at NASA's Goddard Space Flight Center at Greenbelt, Maryland, where instrumentation for a number of spacecraft, including the recent Explorers X and XII, was developed. At the present he is project scientist for the 900 pound Orbiting Geophysical Observatory to be launched in 1963.

Dr. Ludwig is a member of Phi Beta Kappa, Sigma Xi, the American Geophysical Union, and the Institute of Radio Engineers.

Mr. Scull's resume will follow shortly.